

**SELECTION OF A MULTIPLE DISEASE
RESISTANT RUNNER-TYPE PEANUT**

A Thesis

by

MICHAEL ROBERT BARING

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

May 2006

Major Subject: Plant Breeding

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ABSTRACT

Selection of a Multiple Disease Resistant

Runner-Type Peanut. (May 2006)

Michael Robert Baring, B.S., Texas A&M University

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Four $F_{2:4}$ populations of peanut (*Arachis hypogaea* L.) resulting from the complex cross Tamrun 96 X Tx901639-3 X Sun Oleic 95R were grown in three disease nurseries over a 2 year period. Three separate selection techniques were applied to determine which technique would provide the most effective method for selecting a multiple disease resistant, runner-type peanut. Technique I involved selection at a tomato spotted wilt virus nursery during the first cycle of selection and transferring the selections to a *Sclerotinia minor* (Jagger) nursery for a second cycle of selection in year two. Technique II was the reciprocal of Technique I. Technique III involved selection of the populations at a multiple disease nursery for two consecutive years. Selections were based on disease ratings, growth habits, pod and seed characteristics, and oleic/linoleic acid ratios. Disease ratings were scored as percentage infection on a scale of 0 (0% plot infected) to 10 (100% plot infected). Disease severity was also rated on a scale of 1 (symptoms noted, but no yield effects) to 10 (plant death, no yield). There were two final selections for each population using each selection technique that were yield tested over a 2 year period to determine which technique was superior. The yield tests were conducted using completely randomized block design at all three disease nurseries with

an additional disease-free site included. Data for disease ratings, yield, grade, and value per hectare were combined within locations across years. All three selection techniques provided lines with more disease resistance than the parents; however, there was no difference detected between the effectiveness of the three techniques in terms of disease resistance, yield, grade, or value per hectare.

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INTRODUCTION

The cultivated peanut is an important food crop throughout most of the world. The United States is ranked eighth in the world for average area of production, planting 544,320 hectares in 2003 with an average yield of 3.54 metric tons/hectare (t/ha). The average yield was second only to China. The U.S. produces 1,879,372t annually, which ranks fourth among the world leaders in total peanut production (NASS, 2003).

The leading state for peanut production is Georgia, but Texas accounts for 22% of U.S. peanut production. Texas producers plant 111,375 ha annually and harvest an average yield of 3.36t/ha. The state's average yearly peanut production equals 367,335 metric tons and totals 1.27% of the world's production (NASS, 2003). These production figures have fluctuated over the past decades depending upon weather conditions, pest infestations, and disease epidemics.

Diseases account for much of the yield losses incurred by U.S. peanut farmers each year. Several diseases can be controlled by using pesticide applications; however, pesticides are costly and decrease the profit margin. In addition, there are some diseases that cannot be controlled to an acceptable level with any type of pesticide application. Some peanut diseases may only be controlled by genetic resistance utilizing new resistance genes. Although cultivar development is time consuming and expensive, the cost is relatively minute when compared to the overall cost of pesticides, applications,

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and detrimental effects to both crops and non-target beneficial organisms, as well as the potential harmful effects on the environment. Plant breeding is invaluable when focusing on diseases that cannot be controlled by pesticide applications or cultural practices, if sources of resistance genes are available.

LITERATURE REVIEW

Two peanut diseases in Texas that have caused the greatest yield losses over the last 20 years are the tomato spotted wilt virus (TSWV) and Sclerotinia blight.

TSWV is a tospovirus that affects many food crops in addition to peanut. The virus was identified for the first time in South Texas fields as early as 1957 according to A.L. Harrison (Simpson, 1999, personal communication). The first documented case on peanut in Texas was reported in 1974 (Halliwell and Philley, 1974), but the disease did not become a problem of economic proportions until the mid to late 1980's. The largest peanut producing county in South Texas is Frio County and surveys estimated revenue losses in excess of 5 million dollars due to TSWV during the 1986 growing season (Gasch, 1987, personal communications). Additional reports estimated south Texas peanut losses in three counties over a two year period in excess of \$15 million (Black, 1988, personal communications).

The virus is transmitted by several species of thrips, but only two of these species are considered to be the important vectors of the pathogen to peanuts. Tobacco thrips, *Frankliniella fusca* Hinds, and western flower thrips, *Frankliniella occidentalis* Pergande, both vector the TSWV (Sakimura, 1962, 1963; Hobbs et al.1993). The tobacco thrips are responsible for much of the disease transmission in South Texas because they comprise 80% of the total thrips population in Texas peanut fields and they can reach population densities of more than 10 million thrips per hectare (Mitchell and Smith, 1991).

Adult thrips do not become infected with the virus. They must feed on infected plants while in the immature larval stage to acquire the disease. Several days after ingesting the virus the thrips are able to transmit the disease (Bald and Samual, 1931). As the infected larvae which are wingless, mature into winged adults, they become mobile and are able to feed on healthy plants thereby infecting and spreading the virus.

The insecticidal control of thrips has been reported to be as high as 100% control in peanut (Smith and Sams, 1977). Recent studies have not had the same rate of control. The lack of complete control of thrips affects the ability to separate secondary and primary infection (Mitchell, unpublished data). South Texas farmers rarely treat fields for thrips control because of high costs, low control, and damage to beneficial insects.

Sclerotinia minor is a soil borne fungus that attacks several crops including peanut and causes Sclerotinia blight (Kohn, 1979). The disease was first identified in the U.S. on peanut in 1971 in the state of Virginia (Porter and Beute, 1974). The following year it was identified in the southwestern peanut growing region in the state of Oklahoma (Wadsworth, 1979). Sclerotinia blight was not discovered in Texas until 1981 (Sturgeon, 1982), when it was diagnosed in a peanut field in Mason County (Lee, 1988; Woodard and Simpson, 1993). Sclerotinia blight is now widespread in the Central Texas growing region and has been diagnosed at several locations in the West Texas production area (T.A. Lee personal communication, 2004).

A field infested with *Sclerotinia* must be managed properly because eradicating the fungus is difficult. The fungus is disseminated by many methods and sanitation practices, such as power washing equipment when moving from infested fields to clean

fields, have been devised to limit the spread of the pathogen (Horne, 1989; Goldman, 1995). Fungicide treatments are used in fields with a history of Sclerotinia blight, but they are costly and varietal response to treatment is different in each case (Damicone, 1996). *Sclerotinia minor* thrives on many alternate weed hosts such as *Eclipta prostrata* L. (Melouk et al., 1992) and can survive up to 5 years without any host (Porter et al., 1984).

The Texas peanut breeding program has developed cultivars and breeding lines that exhibit tolerance or resistance, depending upon the line, to both TSWV and Sclerotinia blight. Tamspan 90, a Spanish market-type peanut, was released in 1990 because it had a high level of resistance to Sclerotinia blight and yielded 10-48% higher than other Spanish cultivars grown at that time (Smith et al., 1991). The cultivar Tamrun 96, a runner market-type, was released in 1996 because of its tolerance to TSWV and excellent yield potential under adverse conditions (Smith et al., 1998). Tolerance is used in describing the reaction of Tamrun 96 to TSWV because the cultivar actually becomes infected with the virus and shows severe disease symptoms in certain circumstances. However, even though the cultivar is infected and exhibits late season disease symptoms, it will continue to produce peanuts and out-yield susceptible cultivars. The University of Georgia also released a resistant variety 'Georgia Green' which was planted on the majority of peanut land in the southeastern peanut growing region where TSWV is prevalent (Branch, 1996).

The cultivar Tamrun 98, another runner market-type, was released in 1998 for its resistance to Sclerotinia blight and its excellent grade potential (Simpson et al., 2000).

The resistance of Tamrun 98 was achieved by backcrossing the resistant parent, Tamspar 90, with the runner line TP107-11, followed by pedigree selection.

The Texas program has been using pedigree and backcrossing methods with selection techniques designed for creating lines and cultivars with resistance to an individual disease. Screening nurseries in isolated areas were used for screening resistant breeding lines in an environment where a single pathogen, such as TSWV or *S. minor*, was dominant. A trend was noted over the years in which the genotypes selected for TSWV resistance also proved to have good yield potential under *Sclerotinia* pressure. However, most of the selections for *Sclerotinia* resistance did not yield well under TSWV pressure (unpublished data, Baring and Simpson). Now that breeding lines and cultivars have been developed that carry genes for resistance to each of these individual diseases, the emphasis has shifted towards combining these individual resistances into a single line or cultivar to provide multiple disease resistance.

There are many different types of selection techniques used by plant breeders, when attempting to develop disease resistant genotypes, depending upon the pathogen and the desired outcome. The current situation calls for a technique that will allow for selection of resistance to more than one disease within a single breeding line across different locations. Branch et al. (1991) designed a sequential selection technique to minimize genotype x environment interactions when selecting for leafspot resistance across locations in Georgia, North Carolina, and Oklahoma. It was compared to the pedigree and single seed descent (SSD) methods of selection and proved equal to or better than either the pedigree or the SSD methods for simultaneously selecting for high yield

potential and early leafspot resistance. A similar study, but with different diseases, tomato spotted wilt and *Sclerotinia* blight, is the topic of this research.

The main objective of this study was to apply three separate selection techniques to four peanut populations in the presence of TSWV, *Sclerotinia*, or both diseases simultaneously, and to determine which technique provided the best overall lines in terms of disease resistance, yield, grade, and value per hectare.

MATERIALS AND METHODS

The field experiments were conducted at three locations in Texas and at one location in Oklahoma. Location 1 was in the South Texas growing region of Frio County. The site is owned by a cooperator and has been the TSWV screening nursery site (TSWN) for 15 years. This location has a Dvb Duval very fine sandy loam soil type with a 1-3% slope. Location 2 was in the Central Texas growing region at the Texas Agricultural Experiment Station in Erath County. It has been the site of a *Sclerotinia minor* screening nursery for over 20 years. However, in 1998 and 1999, TSWV and soil borne diseases other than *Sclerotinia* were also prevalent in the nursery. Since TSWV, *Sclerotinia*, and other soil borne diseases were found at this site, it was designated as the multiple disease screening nursery (MDN) for this study. This location has Wob Windthorst fine sandy loam soil with a 1-3% slope. Location 3 was near Ft. Cobb, Oklahoma, where a collaborative effort with the USDA in screening for *Sclerotinia* resistance has been established in their *Sclerotinia* blight nursery (SBN). Location 4 was in the West Texas growing region in Gaines County. The West Texas site was chosen to determine the adaptability of the lines in a disease-free environment after selection cycles were completed. Location 4 will be designated as the disease free nursery (DFN) for the purpose of this study. This location has Bs Brownfield fine sand, thin surface (w) soil type. These four test sites represent the four major growing areas of the southwestern peanut-growing region.

Three selection techniques were used in the experiment. The first technique was a sequential method in which the first cycle of selections were made under TSWV

pressure and planted the following year under *Sclerotinia* pressure for a second cycle of selections. The second technique, also a sequential method, was the reciprocal of the first technique. Selections were made under *Sclerotinia* pressure the first year and then planted under TSWV pressure for a second cycle of selections. The third technique was a typical pedigree selection method repeated for two years in a multiple disease-screening nursery. The first and second cycles of selection occurred in the same location.

Peanut breeding populations chosen for this experiment were created by complex crosses that were segregating $F_{2:4}$ plants in the first selection cycle. Four populations were chosen for this experiment with the pedigree Tx896100/Tx901639-3/SunOleic 95R. Tx896100 was the plant identification number for breeding line 6100 in 1989 and it has since been released as Tamrun 96 because of its resistance to TSWV, southern blight caused by *Sclerotium rolfsii* Saccs. and pod rot caused by *Pythium myriotylum* Drechs (Smith et al., 1998).

Breeding line Tx901639-3 is a line that has resistance to several different diseases including tomato spotted wilt, *Sclerotinia* blight, early and late leafspot, and southern blight. Tx901639-3 was not released as a variety due to pod variability and seed characteristics that do not meet industry standards.

SunOleic 95R was released by the University of Florida Agricultural Experiment Station as the first runner market-type variety with the high oleic chemistry (Gorbet and Knauff, 1997). Analysis revealed that while the total oil content of SunOleic 95R was similar at 49% to the widely grown Florunner variety, its oleic to linoleic (O/L) fatty

acid ratio was much different. Typical runner peanuts have a 1:1 to 2:1 ca. O/L fatty acid ratio. SunOleic 95R has an approximate O/L ratio of 29:1. Oleic fatty acid contains a single double-bonded oxygen in its chemistry while linoleic fatty acid has two. Hence, a ratio containing more linoleic acid results in a greater number of double bonded oxygen's being present. A higher concentration of double bonded oxygen increases the chance of oxidation, which results in product rancidity. Data from the University of Florida indicates that the high O/L chemistry in SunOleic 95R can have a 3- to 15-fold increase in shelf-life over normal O/L varieties (Gorbet and Knauff, 1997). While the increased shelf-life of SunOleic 95R is advantageous, it has many of the same characteristics as the widely grown Florunner cultivar, which includes susceptibility to most peanut diseases. The sole reason for this varieties use in the pedigree of these populations was to transfer the high O/L trait into a more disease resistant line.

The four $F_{2:4}$ populations chosen for this present study were segregating for growth habit, pod type, seed characteristics, disease resistance, and O/L ratios.

The first year of planting consisted of 200 $F_{2:4}$ seeds from each of the four populations, space planted .61m apart in a two-row plot at a row spacing of .914m. This format was followed at all three disease screening nurseries during the first cycle of selections. Individual plant selections were based on disease symptoms, plant type, pod characteristics, and seed characteristics in that order. Each of the selections from the first cycle had a random sample of five seeds analyzed for O/L ratio with the initial selection criteria being that the value must be $\geq 10:1$. Lower values have been shown to further segregate into low and intermediate values (unpublished data). Due to a lack of

high O/L selections with good disease ratings, four selections with mid-oleic values between 2:1 and 10:1 were retained for yield testing.

Initially, disease evaluations were conducted by giving individual plots a rating in the field for disease incidence and disease severity. A scale of 0-10 for disease incidence was used where 0= 0% infected plants and 10=100% infected plants. A similar scale of 1-10 was used for severity of the infection within infected plots. A score of 10 for severity was equal to plant death for those plants that were infected. A score of 1 for severity was assigned where symptoms were present but estimated to have no effect on pod yield. Final in-field selections were made based upon a combination of both disease ratings and overall uniformity of plant growth habit.

Disease ratings at the TSWN were made at 128 days after planting (DAP) and 140 DAP, just prior to harvest. Ratings at the MDN were made at 130 and 151 DAP. Ratings at the SBN were made just prior to harvest at approximately 150 DAP due to the travel distance to this site.

The sequential selection methods required that the selections from the TSWN be planted in the SBN and visa versa during the second year of this experiment (Fig. 1). The SBN was infested with *Sclerotinia minor*, which can be seed transmitted. The TSWN is owned by a private cooperator and is *Sclerotinia*-free. To reduce the probability of spreading the *S. minor* to the cooperator's field, selections from the first year out of the SBN were winter increased in the greenhouse as a quarantine measure to insure pathogen-free seed. The harvested, clean seed was then used as a seed source for planting in the second cycle of selections at the TSWN.

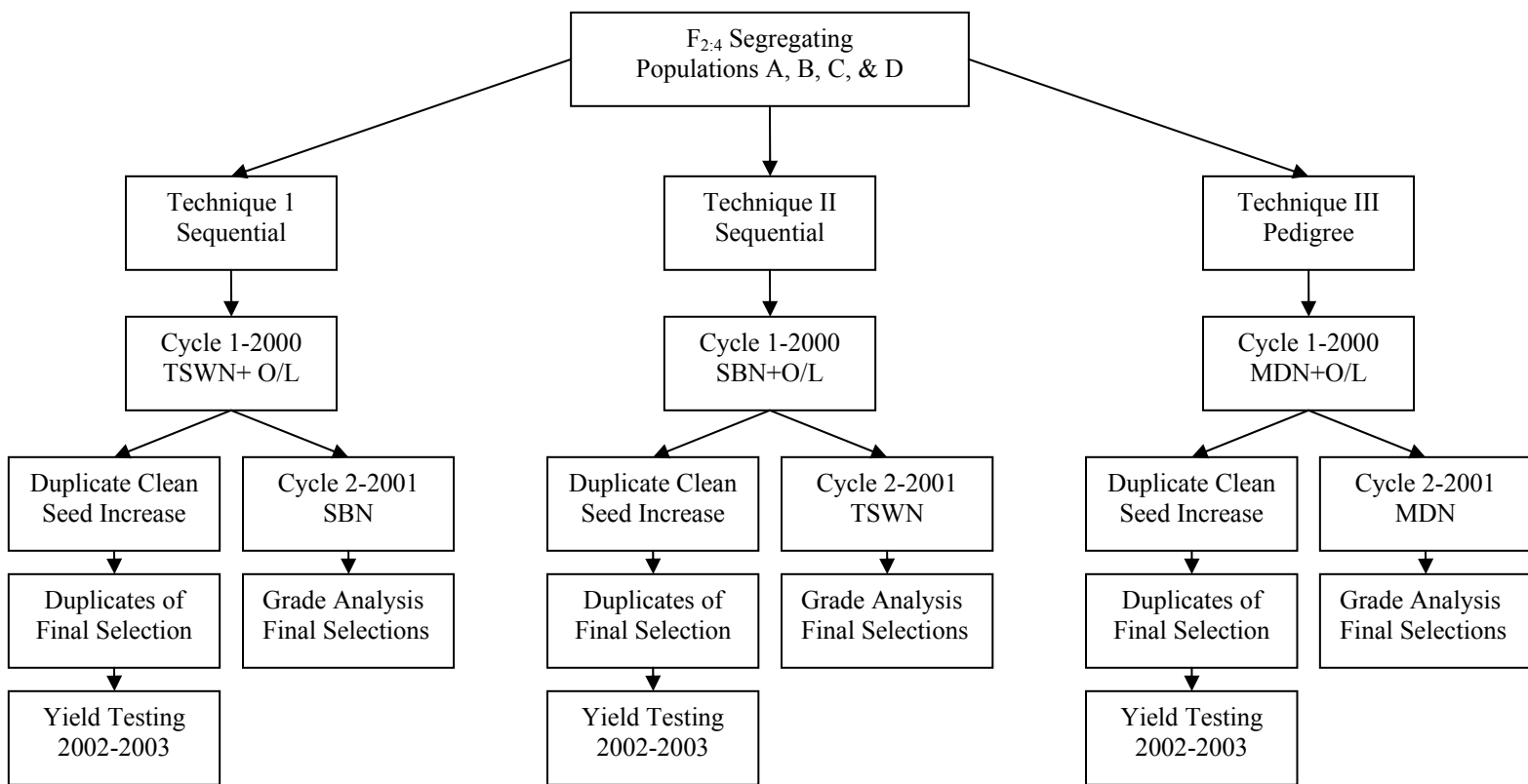


Fig. 1. Pathways of three selection techniques for multiple disease resistance on peanut from initial $F_{2:4}$ segregating populations to the yield testing Phase. SBN=Sclerotinia blight nursery, TSWN=Tomato spotted wilt nursery, MDN=Multiple disease nursery.

The identical problem occurred at the MDN and was solved using the same approach of winter increase in the greenhouse. Although the selections were replanted during the second cycle of selections in the MDN that included *S. minor*, clean seed was needed for yield testing purposes at *Sclerotinia*-free sites during the third and fourth years of the study.

The seeds from the winter greenhouse increase, which were duplicates of the lines in the screening nurseries under the second cycle of selection, were then planted in a disease-free field to insure that a sufficient amount of clean seed was produced so that each final selection could be represented in replicated yield tests.

Selections from the TSWN in the first cycle were planted in the SBN without quarantine because TSWV is not seed transmitted. However, the second cycle of selections, which came from the SBN, could have been infested with *S. minor*. To insure adequate clean seed supplies for yield testing, approximately 40 seeds from each of the selections that were to be planted in the SBN were simultaneously planted as duplicate plant rows in a disease-free field. Once the selections were chosen at the SBN, their duplicate plant row from the disease free field increase was identified and harvested for use in the yield testing stage of the study.

The first year of selections were made as individual plant selections and produced F_{4:5} seeds. These individual plant selections were then represented as plant rows consisting of 35 seeds planted in single row plots approximately 3.65m long X .914m wide during the second year. The second cycle of selections, were re-evaluated for disease ratings, uniformity, pod characteristics and grade attributes.

The top two selections from each of the four populations under all three methods were tested for yield potential during the third and fourth years of the study.

The yield test consisted of the 24 selections (top 2 selections x 4 populations x 3 methods), and the three parents (Tx896100, Tx901639-3, SunOleic 95R), for a total of 27 entries. The yield tests were a completely randomized block design with three replications. Individual plots consisted of two rows and measured 1.828m wide x 4.57m long. The seeding rate for all of the plots was 9.8 seed per meter. These trials were multiple-location with an individual yield test planted at each of the selection nurseries and in an additional disease-free site in West Texas.

The tests were conducted over a 2 year period at which time the data collected were analyzed using SAS General Linear Model to determine the effects of the three selection techniques on disease susceptibility, yield, grade, and value per hectare. A Bartlett's test for homogeneity of variances was applied to the individual locations to determine the effectiveness of combining the data across locations and years (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Selection Cycle 1 - 2000

Technique I

The first selection cycle for Technique I was made at the TSWN in South Texas. Conditions throughout the growing season were favorable for yield potential but screening for the target disease of TSWV was difficult due to low disease incidence. The susceptible variety Tamrun 88 was planted in the nursery as a spreader for the TSWV and bordered every plot. Typically, Tamrun 88 exhibits 80% to 100% infected symptoms at harvest. However, due to low disease incidence in 2000, the Tamrun 88 spreader rows and checks exhibited an average of 8.0% infection per plot while the resistant check US224 had a 0.0% infection rate. Thus, plants exhibiting any TSWV symptoms at harvest were discarded and the remainder of the in-field selection process was made based upon plant type, growth habit and pod type. Disease symptoms were not rated or recorded for individual plants within the segregating populations of this study during the first cycle of selections.

The individual plant selections (IPS) were then hand picked and shelled to examine seed characteristics. Lines were discarded if: 1) seed color was red resembling Valencia's, 2) split seed testas were >20%, 3) wrapped cotyledons were >20%. The remaining lines were analyzed for O/L ratios and all of the lines with initial O/L ratios <2.0 were discarded. Field selections from the four populations in the first cycle of Technique I are listed in Appendix Table A1.

A total of 63 IPS were made out of a possible 800 plants for Technique I-cycle one. O/L analysis and seed evaluations resulted in the removal of an additional 30 selections.

The remaining 33 selections were transferred to location three in Ft. Cobb and planted as F_{4.5} plant rows for the second cycle of Technique I selections in the *Sclerotinia* blight nursery (SBN) (Table 1). Duplicate plant rows of these 33 selections were simultaneously planted in a *Sclerotinia*-free location for pathogen-free seed increase.

Table 1. Number of individuals from each of four populations that were selected during the first cycle of selections in 2000 for continued evaluations.

Population	TSWN	SBN	MDN
Pop 1	13/200	18/200	19/200
Pop 2	5/200	10/200	6/200
Pop 3	9/200	11/200	9/200
Pop 4	6/200	13/200 [#]	3/200
Total	33/800	52/800	37/800

[#]O/L analysis was incomplete at the time of planting and 6/13 population four selections had O/L ratios <2.0 when the data were completed.

Technique II

The first cycle of selections for Technique II was made at Ft. Cobb at the USDA nursery screening for *Sclerotinia* blight (SBN). In 2000, conditions were very dry during the growing season and thus, disease incidence was low. Tamrun 98, the resistant check for *Sclerotinia*, had an average infection rate of 9% while Florunner, the susceptible check had an average infection rate of 20%. Due to the low incidence of disease, the IPS were based primarily on plant types and pod characteristics. The same seed quality criteria that were used in Technique I were also applied to these selections. The individual population selections and their corresponding O/L ratios are listed in the Appendix (Table A2).

A total of 52 IPS were made in the first cycle of Technique II (Table 1). These selections were grown under quarantine in the 2000-01 winter greenhouse. *Sclerotinia*-

free seeds from this increase were planted as $F_{4:6}$ plant rows in the TSWN for the second cycle of selections in 2001.

Technique III

The first cycle of selections for Technique III was made at the MDN. Growing conditions were favorable throughout the season. Although this site had exhibited *Sclerotinia* blight and TSWV for the previous two years, there were no visible TSWV symptoms in the nursery during cycle one. The late season climate of cool temperatures and wet weather provided excellent conditions for growth of *S. minor*. *Sclerotinia* blight was severe with the susceptible check ‘Langley’ completely dead at harvest and the resistant check Tamrun 96 averaging at least 80% infection. The vast majority (~ 85%) of the nursery was dead at harvest. Because the disease pressure was so severe, most plant selections exhibited some disease symptoms. The IPS were processed following the same procedures that were used in Techniques I and II and are noted in the appendix (Table A3).

A total of 37 IPS were harvested and advanced (Table 1). These selections were planted at the same MDN in 2001 as $F_{4:5}$ plant rows to be screened for the second cycle of Technique III selections. Seed from these selections were also increased under quarantine in the 2000-2001 winter greenhouse in College Station. The resulting clean seed was simultaneously planted in *Sclerotinia*-free soil as duplicate plant rows to insure pathogen-free seed for yield testing purposes in years 3 and 4 of this study.

Selection Cycle 2 - 2001

Technique I

The second cycle of selections began in 2001 at the SBN located at Ft. Cobb, OK. Selections from the 2000 TSWN were transferred to the SBN in 2001 for the second selection cycle of Technique I (Fig. 1). Weather conditions were more favorable for *Sclerotinia* with a cool and wet fall and disease severity was moderate. Several selections were completely susceptible, but most of these exhibited minor levels of infection with ratings ranging from 1 to 3 in severity. Several of the lines were segregating for growth habits and these lines were discarded. The remaining plant row selections were harvested and each entry was graded to determine the shelling characteristics according to USDA grading protocol (Appendices 4 to 7).

The top two lines selected for population one were 4501-6 and 4501-7. Line 4501-11 had a higher grade, but poor pod retention and higher disease ratings made it a poor candidate for yield testing (Table A4). Line 4501-2, had lower disease ratings, but it was segregating for growth habit. Lines 4501-6 and 4501-7 had low disease ratings, high O/L values and good grade attributes.

There were only five IPS to analyze for population two from Technique I (Table A5) after the second cycle was complete. Line 4502-2 had low disease ratings, a high grade at 74.9%, and a seed size comparable to current runner varieties at 56.8g/100seed. All of the other selections had higher disease scores and were similar in all aspects, therefore, line 4502-8 was chosen because it had the highest grade value of the remaining lines and a slightly lower infection percentage.

Several selections from population three (Table A6) were discarded due to segregating plant types, but five lines had low disease ratings and were equal in all other aspects. Grades for these lines ranged from 64.4% to 65.9%, therefore, lines 4503-8 and 4503-10 were chosen because they had the lowest disease ratings, uniform runner-type growth habits and high O/L values.

The disease ratings for IPS in population four (Table A7), revealed that the population was more susceptible to *Sclerotinia* than any of the other three populations tested. None of these selections were superior in terms of disease ratings or grade analysis, thus, much of the selection pressure was based upon pod and seed characteristics. Line 4504-8 had the lowest disease rating within the group and excellent pod characteristics, making it a final selection. Unfortunately, two of the four remaining lines were segregating for plant types and a third line had poor pod retention. Thus, line 4504-11 was chosen as a final selection for Technique I population four even though it has an O/L ratio of 3.8 and a higher disease rating than desired for this study.

Technique II

For Technique II, the first cycle selections were moved from the SBN to the TSWN in South Texas for selection in 2001. The TSWV pressure was moderate but symptoms of TSWV were not observed until mid-season. The two ratings taken in the nursery were important because they reflected rating changes in some of the more susceptible lines while other lines that became infected with the virus may have some resistance because their ratings did not change. The most resistant and phenotypically desirable and high

yielding lines were advanced for quality evaluation and selections of the final material were based on these parameters (Tables A8, A9, A10 and A11).

Population one (Table A8) began with 18 IPS. Fourteen of the original 18 lines selected were discarded because of disease susceptibility, segregating plant types, segregating seed colors or low yields. Line 4701-11 was chosen as a final selection because it had good disease ratings and the second highest grade (66.1%) among population one lines. Line 4701-19 was selected because it had a grade of 65.2%, and good pod characteristics even though it had TSWV disease ratings of 5 for severity and 5 for percent of plot infected. One other line, 4701-15, had low disease ratings but had a grade value of 60.5%, which was much lower than the final two selections.

Eight out of the original 10 selections in population two for selection Technique II (Table A9) were discarded due to poor disease ratings, pod loss, and dwarfed growth habits. Line 4702-5 had a disease rating of 9, but was chosen as a final selection because of its excellent pod retention and grade attributes. This line also had an O/L ratio of 2.2 which was lower than the original selection criteria of >10 . There were other lines with higher O/L ratios and lower disease ratings, but they shed pods at harvest, adversely affecting yields. Line 4702-10 had low disease ratings, but the plants were small, almost dwarfed, which caused very poor yield performance. The final selection from this population was 4702-16 which had the lowest disease rating (TSWV = 3) of the group, a grade value of 69.9%, and an O/L ratio of 17.8.

The top two selections for population three under Technique II (Table A10) were chosen because they were tied for the lowest disease ratings and had good pod retention. Lines 4703-1 and 4703-3 each had a final TSWV disease rating of 3. After discarding

three of the original eight lines for segregating plant types, the next closest line in terms of disease ratings was line 4703-5 with a rating of 5, but it had poor pod retention. Line 4703-1 was selected as one of the top two lines even though it had an O/L ratio of 2.2 because there were no other high O/L lines with acceptable disease ratings.

There were three lines in population four under selection Technique II that had a final TSWV disease rating of 3, which was the lowest rating for this population (Table A11). The two lines 4704-8 and 4704-15 had disease ratings of 3 and were selected because they had good pod characteristics and grade values of 68.6% and 69.7%, respectively, with O/L ratios >22.0. Line 4704-13 had a low TSWV rating of 3, but it had poor pod retention at harvest and an O/L ratio of 4.2.

Technique III

Technique III advanced lines were grown for the second consecutive year in the multiple-disease nursery (MDN). The 2001 growing season was similar to the conditions of 2000; the prevalent disease in the nursery was Sclerotinia blight. No TSWV symptoms were observed on any of the selections. Some plants were infected with *Sclerotium rolfsii*, but the majority of the diseased and dead plants were infected by *S. minor*. The most desirable lines, based on agronomic and grade characteristics were advanced for comparison testing (Appendices 12 to 15).

Population one from Technique III (Table A12) began with 18 IPS, but nine of these were discarded due to segregating growth habits. All of the remaining selections had disease ratings of 0 or 1. The final two selections were based upon grade attributes

because all other criteria were similar. Selections 4601-4 and 4601-6 were chosen because they had the highest grade values at 70.1% and 70.3% respectively.

Population two (Table A13) had six lines to evaluate after the second cycle of in-field selecting was complete. Lines 4602-2 and 4602-6 were discarded due to segregation issues and line 4602-3 was discarded because it had a disease rating of 7, which was the highest disease rating for this population. Line 4602-4 had an excellent disease score of 1 and the second highest grade value for this population at 69.3%. Line 4602-9 also had a low disease score of 2 and it was the highest grading line for this population at 70.1%. These two selections had O/L ratios of 14.1 and 19.8 respectively and were chosen as final selections to be yield tested.

Table A14 lists the nine lines chosen from the second cycle of selection Technique III for population three. Seven of these nine lines were discarded due to segregating growth habits, pod characteristics and dwarfed plant types. The remaining two lines, 4603-12 and 4603-13, had final disease ratings of 0 and 1 respectively and grade values of 69.6% and 69.1%. Unfortunately, line 4603-13 had an O/L ratio of 2.9, but had to be used as a final selection due to the paucity of high O/L lines with uniform agronomic traits.

There were only three lines from population four under Technique III (Table A15) that met the selection criteria to get to the final evaluation. Line 4604-4 had a disease rating of 0 and an average grade value of 67.1%. The final line selected was 4604-5. It was moderately susceptible with a final disease rating of 4 and had an average grade value of 64.3%. Line 4604-3 was still segregating for both growth habit and O/L value, so it was discarded.

A list of the final 24 lines selected and the populations and techniques that they each represent can be found in Table 2.

Table 2. Final selections from four segregating peanut populations for three different selection techniques to be yield tested during the 2002-03 growing season.

Selection	Entry	Population	Technique
4701-11	1	1	2
4701-19	2	1	2
4702-5	3	2	2
4702-16	4	2	2
4703-1	5	3	2
4703-3	6	3	2
4704-8	7	4	2
4704-15	8	4	2
4601-4	9	1	3
4601-6	10	1	3
4602-4	11	2	3
4602-9	12	2	3
4603-12	13	3	3
4603-13	14	3	3
4604-4	15	4	3
4604-5	16	4	3
4501-6	17	1	1
4501-7	18	1	1
4502-2	19	2	1
4502-8	20	2	1
4503-8	21	3	1
4503-10	22	3	1
4504-8	23	4	1
4504-11	24	4	1

The top two lines from each of the four populations under each of the three selections techniques were selected to increase statistical powers in determining technique effects on disease ratings, yield, grade, and value per acre.

Yield Testing (2003-2004)

TSWN Location

The TSWN began both growing seasons with good moisture and plant stands. The 2002 growing season ended with a Gulf coast hurricane at the time of harvest, but no effects on yield or quality were seen. Test yields were high with a mean yield of 6904 kg/ha and the average grade at 71.9% total sound mature kernels (TSMK). The average value per ha (\$/ha) was \$2712.

Two weeks post-emergence of the 2003 test, a severe storm with 112Kmph winds and 12.7cm of rainfall damaged the nursery. The force of the wind and rain eroded approximately 3.8cm of soil away from the base of the cotyledonary stem. This resulted in a reduction of plant stability for several weeks until lateral branches eventually spread across the ground and natural pegging of the peanut plant allowed it to recover stability. The crop was temporarily stunted and crop maturity took two weeks longer than typical for the nursery. Even though the crop took longer to mature, there were no indications that this event had any adverse effect on the crop because yield and grades were comparable to previous years. The mean yield for the test was 6999 kg/ha with an average grade of 70.9% TSMK, which led to an average gross value of \$2697.

Neither the 2002 nor the 2003 growing season had high levels of disease due to TSWV. TSWV incidence was so low that for better separation, symptoms were recorded on a percentage of the plot infected instead of the original 0-10 scale. During the 2002 season, the susceptible check Sun Oleic 95R had a mean TSWV plot infection of 26% prior to harvest. The resistant check Tamrun 96 had 13% infection. In 2003, the disease infection rate for SunOleic 95R was 29% while Tamrun 96 had 1% infection.

Table 3. The effects of selection techniques, populations, genotypes, and interactions between these terms on yield, grade, value per hectare, and disease ratings at the tomato spotted wilt nursery during 2002 and 2003 yield testing.

Effects and Interactions	Yield kg/ha	Grade %TSMK	Value \$/ha	TSWV Ratings
Years	ns	**	ns	ns
Populations	ns	*	ns	*
Pop*Years	ns	ns	ns	ns
Techniques	ns	ns	ns	ns
Tech*Years	ns	ns	ns	ns
Pop*Tech	*	ns	ns	**
Pop*Tech*Years	ns	*	ns	ns
Gen(Pop*Tech)	*	ns	ns	ns
Gen*Year(Pop*Tech)	*	**	*	ns

*Significantly different ($P \leq 0.05$), **($P \leq 0.01$), and ns, not significant.

In analysis across years in the TSWN, most effects were not significant (Table 3). For yield, significant effects were detected only for genotypes and two interaction terms. For grade, main effects due to year and populations were detected with population two having had the highest mean grade at 74.3% ($p < 0.025$). Population two also had the lowest mean TSWV rating at 5.3% ($p < 0.01$). At this location, techniques had no effect on yield, grade, value, or disease ratings. However, the population x technique interaction was significant for yield and disease rating indicating that different populations responded differently to certain selection schemes. Additionally, the genotype x year interaction was significant for all but disease reaction, indicating that genotypes reacted differently across years.

MDN Location

Location two, the MDN, was affected during the 2002 growing season by late rainfall events that increased Sclerotinia blight and delayed harvest. Mean yields for the test were lower than expected at 1569 kg/ha as compared to 2551 kg/ha in 2003. Sclerotinia blight was dominant in the nursery and no TSWV was observed. *Sclerotinia* ratings ranged from a high infection rate of 9 (90%) to a low infection rate of 2 (20%). The test mean disease rating was 5.4 in 2002 with the susceptible check Sun Oleic 95R averaging 6.3. The *Sclerotinia* ratings for 2003 ranged from 1 to 6 and the susceptible check had a mean rating of 4.0 with a test mean rating of 4.0.

Table 4. The effects of selection techniques, populations, genotypes, and interactions between these terms on yield, grade, value per hectare, and disease ratings at the multiple disease nursery during 2002 and 2003 yield testing.

Effects and Interactions	Yield Kg/ha	Grade %TSMK	Value \$/ha	<i>Sclerotinia</i> Ratings
Year	**	**	**	**
Population	ns	ns	ns	ns
Pop*Year	*	**	**	**
Technique	ns	ns	ns	ns
Tech*Year	*	ns	*	*
Pop*Tech	ns	ns	ns	ns
Pop*Tech*Year	**	ns	**	*
Gen(Pop*Tech)	ns	ns	ns	ns
Gen*Year(Pop*Tech)	*	ns	*	*

*Significantly different ($P \leq 0.05$), ** ($P \leq 0.01$), and ns, no difference.

Analysis across years at the MDN revealed that the two years of testing were different (Table 4). At this location, for yield, grade, value, and disease ratings, no significant effects were detected for populations, techniques, or genotypes. For yield, value, and

disease ratings, all of the interaction terms that included years were significant indicating that the populations, the techniques, and the genotypes reacted differently across years.

Additionally, analysis from each individual year showed significant differences among populations, but the population differences were not consistent from year to year. For example; population two had the highest grade at 65.6% ($p = .0094$) in 2002, but in 2003, populations one and three had the highest grades at 70.5% and 72.2% ($p = .0005$) respectively.

SBN Location

Location three, the SBN in Oklahoma, had good moisture and plant stands at the beginning of each growing season. Sclerotinia blight was moderate in 2002 with the susceptible check Sun Oleic 95R having an infection rating of 7.3 (73%) and the resistant check Tamrun 96 had an infection rating of 4.9. The mean test yield was 2348 kg/ha with a mean test grade of 69.6% TSMK.

Disease incidence in 2003 was lower at the SBN. The susceptible check had a disease rating of 5.6 while the resistant check had a rating of 2.1. Due to a lack of rainfall, conditions were not as conducive for disease in 2003 as in 2002. The low disease pressure translated to higher yields than in 2002. The 2003 mean test yield was 3234 kg/ha, which was nearly 1000 kg/ha higher than the test yield for 2002. The mean test grade was 63.4% TSMK, which resulted in an average gross income of \$1114/ha.

Table 5. The effects of selection techniques, populations, genotypes, and interactions between these terms on yield, grade, value per hectare, and disease ratings at the Sclerotinia blight nursery during 2002 and 2003 yield testing.

Effects and Interactions	Yield kg/ha	Grade %TSMK	Value \$/ha	<i>Sclerotinia</i> Ratings
Years	**	**	**	*
Populations	ns	**	**	ns
Pop*Years	*	ns	ns	*
Techniques	ns	ns	ns	ns
Tech*Years	*	*	*	*
Pop*Tech	ns	**	ns	ns
Pop*Tech*Years	*	ns	*	ns
Gen(Pop*Tech)	ns	ns	ns	**
Gen*Year(Pop*Tech)	**	**	**	ns

*Significantly different ($P \leq 0.05$), ** ($P \leq 0.01$), and ns, no difference.

In analysis across years at the SBN, the two years were different (Table 5). Most of the other main effects were not significant except for populations. For grade and value, main effects due to populations were detected with population two having the highest mean grade at 69.5% ($p < 0.005$) and the highest mean value at \$1178 ($p < 0.01$). At this location, technique had no effect on yield, grade, value, or disease ratings. The pop*tech interaction for grade was significant indicating that different populations responded differently to certain selection schemes. Most of the interaction terms that include years were significant indicating that the populations, techniques and genotypes reacted differently across years.

DFN Location

Plants at location four, the DFN in West Texas were slow to emerge in 2002 due to low temperatures (approximately 4°C for two consecutive nights after planting). Typically, emergence occurs 7 to 10 days after planting, but with the low temperatures,

emergence was delayed until 15 DAP. However, stand counts were normal after emergence and the plants recovered from the late start. Weather conditions throughout the growing season were hot with day time temperatures reaching 38°C for much of July and August. These extreme temperatures resulted in a need for continuous irrigation. Plants developed necrosis at the leaf margin due to excessive salt exposure brought on by continuous irrigation with high sodium content water. Symptoms were uniform across the test and no adverse effects on yield were observed. The mean yield for the test was 6332 kg/ha with an average grade of 74.4%, which resulted in an average gross value of \$2601/ha.

The weather conditions for the 2003 growing season were more extreme than in 2002. High daytime temperatures in excess of 38°C and low night-time temperatures below 21°C near the end of the growing season during the crucial period of pod maturation damaged the crop. Typical peanut maturation in west Texas occurs at approximately 155 DAP depending upon weather conditions. The crop in 2003 did not fully mature even after being left in the field until 160 DAP, which resulted in lower than expected yields, grades, and value per ha. The mean test yield in 2003 was 5623 kg/ha which was 710 kg/ha lower than 2002. The mean test grade was 71.4% TSMK, which was 3% lower than 2002, and as a result, the mean value/ha was \$2171 which was also \$430/ha lower.

The data were combined across years like the other three locations, however, because this was a disease-free location there is no column for combined analysis of disease ratings (Table 6).

Table 6. The effects of selection techniques, populations, genotypes, and interactions between these terms on yield, grade, and value per hectare at the disease-free nursery during 2002 and 2003 yield testing.

Effects and Interactions	Yield Kg/ha	Grade %TSMK	Value \$/ha
Years	**	**	**
Populations	ns	*	ns
Pop*Years	**	ns	**
Techniques	ns	*	ns
Tech*Years	*	ns	*
Pop*Tech	ns	ns	ns
Pop*Tech*Years	**	*	**
Gen(Pop*Tech)	**	ns	ns
Gen*Year(Pop*Tech)	ns	**	ns

*Significantly different ($P \leq 0.05$), ** ($P \leq 0.01$), and ns, no difference.

The analysis across years in the DFN reveal that the years were different ($p=0.0118$). For yield, significant effects were detected for genotypes with genotype 1 from population one and Technique II having the highest mean yield at 6721 kg/ha ($p<0.01$). Three of the four interaction terms that included years were different indicating that the populations, techniques and genotypes reacted differently across the two years. For grade, main effects were detected for populations and techniques with population two having the highest mean grade of 75.1%TSMK ($p<0.05$) and Technique III having the highest mean grade of 74.0% ($p<0.05$). For value, the interaction terms that included years were significant indicating that the populations and the techniques reacted differently across the two years.

Combined Analysis

Initially, yield data for each individual location from both 2002 and 2003 were analyzed separately and a Bartlett's Test for homogeneity was conducted to determine whether the data could be combined across locations and years (Table 7).

Table 7. Bartlett's test for homogeneity of variances for the yield factor across four locations and two years.

Year	Location	County	f_t	$(f_t s_i^2)$	s_i^2	$\log_e s_i^2$	$f_t \log_e s_i^2$
2002	1-TSWN	Frio	46	6421305	139594	11.8465	544.939
2002	2-MDN	Erath	46	6011128	130677	11.7805	541.903
2002	3-SBN	Ft. Cobb	42	2397011	57072	10.5921	444.868
2002	4-DFN	Gaines	42	13442932	320070	12.6762	532.400
2003	1-TSWN	Frio	46	16228395	352791	12.7736	587.586
2003	2-MDN	Erath	46	15672389	340704	12.7388	585.985
2003	3-SBN	Ft. Cobb	46	5166485	112315	11.6291	534.939
2003	4-DFN	Gaines	46	5449119	118459	11.6823	537.386
Total			360	70788765	1571681	95.7191	4310.005

The X_2 value for the Bartlett's Test was 77.43 for pod yield and with 7 degrees of freedom the probability of finding a value greater than 77.43 was less than 0.001. The same conclusions were reached for the grade and value analysis. Thus, the variances were unequal and the data could not be combined across locations and years based on the assumption of statistical analyses. Transformations were attempted in an effort to normalize the data, but none were effective such that the data could be combined across location and years. Nevertheless, the data were combined to determine the relative effect of all factors in this analysis.

The results of the combined analysis are listed in Table 8. There was no combined analysis across all locations for disease ratings because different diseases were being rated and different rating systems were used depending upon the disease nursery.

Table 8. Combined analysis to detect source effects for yield, grade and value per hectare in replicated tests at four nurseries across two years.

Source	Yield	Grade	Value
Location	**	**	**
Year	**	ns	**
Loc*Year	**	**	**
Rep(Loc*Year)	ns	*	ns
Population	*	**	**
Pop*Loc	**	ns	**
Pop*Year	ns	**	ns
Pop*Loc*Year	ns	*	ns
Technique	ns	**	ns
Tech*Loc	**	ns	**
Tech*Year	ns	ns	ns
Tech*Loc*Year	ns	ns	ns
Pop*Tech	ns	**	ns
Pop*Tech*Loc	ns	*	*
Pop*Tech*Year	ns	ns	ns
Pop*Tech*Loc*Year	ns	ns	ns
Gen(Pop*Tech)	**	**	**
Gen*Loc(Pop*Tech)	ns	ns	ns
Gen*Year(Pop*Tech)	ns	ns	ns
Gen*Loc*Year(Pop*Tech)	ns	**	ns

*Significantly different ($P \leq 0.05$), ** ($P \leq 0.01$), and ns, not significant.

The combined analysis determined that locations were different ($p = 0.0001$) for all three traits measured. Years were also different ($p = 0.001$) for yield and value, but not different for grades ($p=0.09$). Interactions between years and locations were occurring for all three traits ($p=0.0001$). Due to the large differences in locations, the combined analysis across locations and years was not practical.

CONCLUSIONS

Multiple disease resistance in terms of a combined resistance to both TSWV and *Sclerotinia minor* was accomplished in which individual lines were produced with better disease resistance than the parents. Comparisons between the parents and the individual lines selected were not essential to this study for detecting differences between the techniques and were therefore omitted. It is worth noting that when disease incidence was elevated, as in the 2002 TSWV nursery where the resistant check Tamrun 96 had a rating of 13.5, there were six lines with superior ratings that ranged from 1.0 to 2.1 ($p \leq 0.05$). All three techniques were represented in these six lines and this trend was observed at each of the disease nurseries when disease incidence was elevated.

Individual location analysis for each year showed differences between techniques for many of the traits measured depending upon the year and the location analyzed. A Bartlett's test proved that the data should not be combined across years and locations. However, the data were combined across years within locations to make sound scientific inferences about the data. The combined data from each location showed trends in which few main effects due to population, technique, or genotypes were detected. However, there were differences for almost every interaction term in which years were involved suggesting that the populations, the techniques, and the genotypes reacted differently between the years. Additionally, differences were hard to detect due to the small number of degrees of freedom in the model.

In the first year of yield testing, the planting rate was 9.8 seeds/m with 3 replications/location, which was due to limited seed availability. The number of replications and the amount of seed per meter planted could have been increased during

the second year of yield testing, but the decision was made to maintain uniformity across the two years of yield testing for the purpose of this study. Theoretically, increasing the number of replications per location and additional years of yield test data could increase the number of degrees of freedom in the model to a point at which separation and differences could be detected between the techniques.

Based on the information gathered through this study all three selection techniques were equally as effective in providing lines with multiple disease resistance superior to the parents. In terms of efficiency, Technique III would be the most efficient in that all of the selection work could be conducted at one location without having to transfer breeding lines between locations which, in this study, were over 800 Km apart.

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APPENDIX A

Table A1. Individual plant selections and corresponding O/L values for four peanut breeding populations after the first cycle of selections in 2000 for technique I at the tomato spotted wilt virus nursery.

Pop 1	O/L	Pop 2	O/L	Pop 3	O/L	Pop 4	O/L
4501-1	24.3	4502-1	33.2	4503-1	1.6 ^D	4504-1	2.0
4501-2	15.1	4502-2	27.9	4503-2	13.4	4504-2	1.7 ^D
4501-3	Disc. ^A	4502-3	3.0	4503-3	2.8	4504-3	10.7
4501-4	Disc. ^A	4502-4	3.0	4503-4	1.8 ^D	4504-4	21.8
4501-5	12.4	4502-5	2.4	4503-5	1.8 ^D	4504-5	Disc. ^B
4501-6	15.7	4502-6	33.2	4503-6	15.0	4504-6	1.9 ^D
4501-7	23.6	4502-7	2.6	4503-7	3.3	4504-7	3.0
4501-8	14.2	4502-8	33.6	4503-8	24.7	4504-8	21.4
4501-9	9.9	4502-9	2.4	4503-9	25.1	4504-9	22.9
4501-10	12.0	4502-10	5.6	4503-10	27.7	4504-10	2.0
4501-11	11.9	4502-11	2.1	4503-11	5.7	4504-11	3.8
4501-12	12.8	4502-12	1.9 ^D	4503-12	26.0	4504-12	3.0
4501-13	11.7			4503-13	2.1	4504-13	Disc. ^C
4501-14	10.5			4503-14	1.8 ^D	4504-14	1.6 ^D
4501-15	24.6			4503-15	1.7 ^D	4504-15	Disc. ^C
				4503-16	30.9	4504-16	1.7 ^D
				4503-17	1.7 ^D	4504-17	1.6 ^D
				4503-18	5.7	4504-18	22.1

Oleic to Linoleic fatty acid ratio (O/L) based on five seed samples.

^ALine was discarded due to red colored seed testa.

^BLine was discarded due to >20% split seed testa.

^CLine was discarded due to >20% wrapped cotyledon.

^DLine was discarded due to O/L ratio <2.0.

Table A2. Individual plant selections and corresponding O/L values for four peanut breeding populations after the first cycle of selections in 2000 for technique II at the Sclerotinia blight nursery.

Pop 1	O/L	Pop 2	O/L	Pop 3	O/L	Pop 4	O/L
4701-1	21.7	4702-1	20.8	4703-1	2.2	4704-1	1.4 ^E
4701-2	19.6	4702-2	1.9 ^D	4703-2	1.4 ^D	4704-2	24.3
4701-3	16.9	4702-3	30.1	4703-3	15.5	4704-3	1.4 ^E
4701-4	15.6	4702-4	2.8	4703-4	10.4	4704-4	1.6 ^E
4701-5	Disc. ^A	4702-5	2.2	4703-5	25.6	4704-5	1.6 ^E
4701-6	Disc. ^A	4702-6	Disc. ^C	4703-6	1.4 ^D	4704-6	1.5 ^E
4701-7	14.7	4702-7	37.1	4703-7	26.7	4704-7	1.4 ^D
4701-8	12.8	4702-8	1.8 ^D	4703-8	1.2 ^D	4704-8	22.0
4701-9	Disc. ^A	4702-9	1.5 ^D	4703-9	1.7 ^E	4704-9	1.3 ^D
4701-10	19.8	4702-10	13.6	4703-10	1.5 ^D	4704-10	1.4 ^E
4701-11	14.3	4702-11	1.3 ^D	4703-11	28.3	4704-11	28.2
4701-12	Disc. ^A	4702-12	1.6 ^D	4703-12	1.7 ^E	4704-12	25.1
4701-13	26.1	4702-13	2.4	4703-13	1.8 ^E	4704-13	4.2
4701-14	22.9	4702-14	20.7	4703-14	7.7	4704-14	15.0
4701-15	17.4	4702-15	18.1	4703-15	20.2	4704-15	26.0
4701-16	18.8	4702-16	17.8	4703-16	1.7 ^E	4704-16	1.7 ^D
4701-17	20.0			4703-17	3.2	4704-17	1.7 ^D
4701-18	15.6					4704-18	1.3 ^D
4701-19	24.3						
4701-20	23.8						
4701-21	15.3						
4701-22	19.4						

Oleic to Linoleic fatty acid ratio (O/L) based on five seed samples.

^ALine was discarded due to red colored seed testa.

^BLine was discarded due to >20% split seed testa.

^CLine was discarded due to >20% wrapped cotyledon.

^DLine was discarded due to O/L ratio <2.0.

^EChemical analysis is a lengthy process therefore, not all of the selections were analyzed for O/L chemistry before planting in 2001. Thus, some of the above lines are not marked

^D for discard and could not be deleted until mid season after the analysis was completed.

Table A3. Individual plant selections and corresponding O/L values for four peanut breeding populations after the first cycle of selections in 2000 for technique III at the multiple disease nursery.

Pop 1	O/L	Pop 2	O/L	Pop 3	O/L	Pop 4	O/L
4601-1	14.4	4602-1	2.4 ^D	4603-1	2.3 ^D	4604-1	1.4 ^D
4601-2	13.7	4602-2	21.8	4603-2	1.9 ^D	4604-2	1.3 ^D
4601-3	14.7	4602-3	21.5	4603-3	1.2 ^D	4604-3	3.4
4601-4	17.1	4602-4	14.1	4603-4	14.6	4604-4	14.1
4601-5	13.1	4602-5	3.1	4603-5	15.2	4604-5	14.8
4601-6	15.8	4602-6	5.1	4603-6	18.6	4604-6	1.4 ^D
4601-7	13.9	4602-7	1.8 ^D	4603-7	17.1	4604-7	1.4 ^D
4601-8	11.8	4602-8	1.7 ^D	4603-8	15.8	4604-8	1.1 ^D
4601-9	11.9	4602-9	19.8	4603-9	1.4 ^D	4604-9	1.5 ^D
4601-10	10.1	4602-10	1.5 ^D	4603-10	2.3 ^D	4604-10	1.1 ^D
4601-11	Disc. ^A	4602-11	2.4 ^D	4603-11	16.7	4604-11	1.2 ^D
4601-12	16.6	4602-12	1.7 ^D	4603-12	14.5	4604-12	2.2 ^D
4601-13	12.7	4602-13	1.5 ^D	4603-13	2.9	4604-13	1.2 ^D
4601-14	12.9			4603-14	1.1 ^D	4604-14	1.1 ^D
4601-15	13.9			4603-15	16.1		
4601-16	15.3						
4601-17	11.5						
4601-18	13.1						
4601-19	14.8						

Oleic to Linoleic fatty acid ratio (O/L) based on five seed samples.

^ALine was discarded due to red colored seed testa.

^BLine was discarded due to >20% split seed testa.

^CLine was discarded due to >20% wrapped cotyledon.

^DLine was discarded due to O/L ratio <2.0.

Table A4. Disease ratings and agronomic characteristics for the second cycle of selections for population one under technique I at the Sclerotinia blight nursery in 2001.

Selection	Incidence	Severity	Discard	Grade	100sd./g	O/L
4501-1	4	3	Segregating			24.3
4501-2	2	1	Segregating			15.1
4501-5	6	3	Disease			12.4
4501-6§	3	2		67.9	55.6	15.7
4501-7§	2	2		66.3	61.6	23.6
4501-8	4	3	Poor yield			14.2
4501-9	3	2	Segregating	69.2	59.0	9.9
4501-10	7	3	Segregating			12.0
4501-11	8	4		70.4	73.3	11.9
4501-12	3	3	Segregating			12.8
4501-13	3	1	Pod Charac.			11.7
4501-14	9	5	Disease			10.5
4501-15	7	3	Disease			24.6

Disease incidence scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

Disease severity scale (1-10) with 1 equal to no effect on plant yield due to disease symptoms and 10 equal to plant death for the infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A5. Disease ratings and agronomic characteristics of the second cycle of selections for population two under technique I at the Sclerotinia blight nursery in 2001.

Selection	Incidence	Severity	Discard	Grade	100sd./g	O/L
4502-1	9	5	Disease			33.2
4502-2§	1	2		74.9	56.8	27.9
4502-6	8	6	Segregating			33.2
4502-8§	6	3		74.8	67.3	33.6
4502-10	7	2		72.7	58.2	5.6

Disease incidence scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

Disease severity scale (1-10) with 1 equal to no effect on plant yield due to disease symptoms and 10 equal to plant death for the infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A6. Disease ratings and agronomic characteristics for the second cycle of selections for population three under technique I at the Sclerotinia blight nursery in 2001.

Selection	Incidence	Severity	Discard	Grade	100sd./g	O/L
4503-2	3	2	Segregating	64.7	57.4	13.4
4503-6	3	2		64.6	61.8	15.0
4503-8§	1	2		64.4	55.8	24.7
4503-9	5	3		65.6	53.6	25.1
4503-10§	1	2		65.9	56.2	27.7
4503-11	10	10	Disease			5.7
4503-12	3	2	Segregating			26.0
4503-16	3	2	Segregating			30.9
4503-18	3	2	Pod Charac.			5.7

Disease incidence scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

Disease severity scale (1-10) with 1 equal to no effect on plant yield due to disease symptoms and 10 equal to plant death for the infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A7. Disease ratings and agronomic characteristics for the second cycle of selections for population four under technique I at the Sclerotinia blight nursery in 2001.

Selection	Incidence	Severity	Discard	Grade	100sd./g	O/L
4504-3	9	4	Segregating			10.7
4504-4	8	5				21.8
4504-8§	6	4	Pod Loss	69.6	59.1	21.4
4504-9	8	3		67.5	61.6	22.9
4504-11§	8	4		68.2	58.4	3.8

Disease incidence scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

Disease severity scale (1-10) with 1 equal to no effect on plant yield due to disease symptoms and 10 equal to plant death for the infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A8. Disease ratings and agronomic characteristics for the second cycle of selections for population one under technique II at the tomato spotted wilt virus nursery in 2001.

Selection	128rating	140rating	Discard	Grade	100sd/g.	O/L
4701-1	2	2		63.6	57.3	21.7
4701-2	7	7	Disease			19.6
4701-3	4	4	Segregating			16.9
4701-4	3	3	Segregating			15.6
4701-7	2	3	Segregating			14.7
4701-8	4	6	Disease			12.8
4701-10	3	3	10% Red	69.0	55.3	19.8
4701-11§	2	2		66.1	61.0	14.3
4701-13	4	4	Dormancy			26.1
4701-14	4	5	Disease			22.9
4701-15	2	2		60.5	52.1	17.4
4701-16	4	5	Disease			18.8
4701-17	4	6	Disease			20.0
4701-18	7	8	Segregating			15.6
4701-19§	5	5		65.2	62.2	24.3
4701-20	6	6	Disease			23.8
4701-21	3	3	5% Red	66.0	51.6	15.3
4701-22	3	4	Pod Loss			19.4

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A9. Disease ratings and agronomic characteristics for the second cycle of selections for population two under technique II at the tomato spotted wilt virus nursery in 2001.

Selection	128rating	140rating	Discard	Grade	100sd/g.	O/L
4702-1	8	10	Disease			20.8
4702-3	7	8	Disease			30.1
4702-4	8	10	Disease			2.8
4702-5§	7	9		72.6	57.4	2.2
4702-7	7	9	Disease			37.1
4702-10	3	4	Dwarfed			13.6
4702-13	5	8	Disease			2.4
4702-14	6	8	Pod Loss			20.7
4702-15	5	6	Pod Loss			18.1
4702-16§	2	3		69.9	62.4	17.8

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A10. Disease ratings and agronomic characteristics for the second cycle of selections for population three under technique II at the tomato spotted wilt virus nursery in 2001.

Selection	128rating	140rating	Discard	Grade	100sd/g.	O/L
4703-1§	2	3		67.1	58.8	2.2
4703-3§	3	3		60.6	49.9	15.5
4703-4	3	6	Disease			10.4
4703-5	4	5	Pod Loss			25.6
4703-7	6	8	Disease			26.7
4703-11	3	4	Segregating	66.9	57.5	28.3
4703-14	4	6	Segregating			7.7
4703-17	3	5	Segregating			3.2

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A11. Disease ratings and agronomic characteristics for the second cycle of selections for population four under technique II at the tomato spotted wilt virus nursery in 2001.

Selection	128rating	140rating	Discard	Grade	100sd/g.	O/L
4704-2	4	5	Segregating			24.3
4704-8§	2	3		68.6	59.2	22.0
4704-11	4	5	Segregating			28.2
4704-12	4	5	Animal			25.1
4704-13	2	3	Low Yield			4.2
4704-14	4	5	Segregating			15.0
4704-15§	2	3		69.7	57.2	26.0

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A12. Disease ratings and agronomic characteristics for the second cycle of selections for population one under technique III at the multiple disease nursery in 2001.

Selection	130rating	151rating	Discard	Grade	100sd/g.	O/L
4601-1	0	0		67.6		14.4
4601-2	1	1		69.0		13.7
4601-3	1	1		67.1		14.7
4601-4§	1	1		70.1		17.1
4601-5	1	1		66.4		13.1
4601-6§	1	1		70.3		15.8
4601-7	1	1	Segregating			13.9
4601-8	2	2	Segregating			11.8
4601-9	2	2	Segregating			11.9
4601-10	2	2	Segregating			10.1
4601-12	1	1		62.2		16.6
4601-13	1	2	Segregating			12.7
4601-14	1	1	Dwarfed			12.9
4601-15	1	2	Segregating			13.9
4601-16	2	3	Segregating			15.3
4601-17	2	2	Segregating			11.5
4601-18	1	1	Segregating	65.6		13.1
4601-19	2	3	Pod Loss	68.2		14.8

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Table A13. Disease ratings and agronomic characteristics for the second cycle of selections for population two under technique III at the multiple disease nursery in 2001.

Selection	130rating	151rating	Discard	Grade	100sd/g.	O/L
4602-2	2	3	Segregating Disease			21.8
4602-3	4	7				21.5
4602-4§	1	1		69.3	52.3	14.1
4602-5	2	3		62.1	54.3	3.1
4602-6	3	3	Segregating			5.1
4602-9§	2	2		70.1	54.1	19.8

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A14. Disease ratings and agronomic characteristics for the second cycle of selections for population three under technique III at the multiple disease nursery in 2001.

Selection	130rating	151rating	Discard	Grade	100sd/g.	O/L
4603-4	1	1	Poor Stand			14.6
4603-5	0	1	Segregating			15.2
4603-6	1	1	Segregating			18.6
4603-7	2	2	Pod charac.	63.1	51.5	17.1
4603-8	2	2	Segregating			15.8
4603-11	2	2	Dwarfed			16.7
4603-12§	0	0		69.6	55.1	14.5
4603-13§	1	1		69.1	53.2	2.9
4603-15	0	0	Dwarfed			16.1

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

Table A15. Disease ratings and agronomic characteristics for the second cycle of selections for population four under technique III at the multiple disease nursery in 2001.

Selection	130rating	151rating	Discard	Grade	100sd/g.	O/L
4604-3	3	3	Segregating			3.4
4604-4§	0	0		67.1	53.1	14.1
4604-5§	4	4		64.3	48.3	14.8

Disease rating scale (0-10) with 0 equal to no plants infected and 10 equal to 100% infected plants.

§Lines chosen as final selections to be entered into yield testing phase of the study.

Grades are based on USDA protocol for grading procedures.

Oleic to linoleic fatty acid ratios (O/L) based on five seed samples.

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